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Biosecurity and Risk Management for Dairy Replacements

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Infectious diseases are a major cause of economic loss to dairy heifer producers as a result of calf mortality and culling losses, costs associated with treatment and control of disease, and effects on production such as delayed age at first calving [1–6]. In addition, herd replacements can serve as reservoirs of economically important infectious diseases for the adult herd (eg, Johne's disease or bovine viral diarrhoea virus [BVDV]) [7–10]. The introduction of new pathogens, or the spread of pathogens already present in the herd to new groups of animals, can have a devastating effect on the individual dairy operation [11,12]. In addition, several infectious disease agents commonly found in dairy heifers are zoonotic and their control has public health implications [13–16]. The prevention and control of infectious disease in replacement heifers is therefore an important component of any herd health plan.

Control of infectious diseases relies on increasing host resistance to infection, removing reservoirs of infection, and preventing contacts that result in transmission [17]. Biosecurity and biocontainment programs, either formal or informal, are part of the overall approach to control of infectious disease. In the context of this article, biosecurity at the farm level refers to the outcome of all actions aimed at keeping infectious agents that are not present on an operation from being introduced. Biocontainment refers to the outcome of all actions aimed at controlling the spread of infectious agents (or disease) within and between groups of animals once the agent is present on the operation [18].

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Dairy heifers in North America are typically raised in continuous-flow systems under conditions that provide ample opportunity for the introduction of infectious disease agents and their spread within and between age groups. The National Animal Health Monitoring System (NAHMS) Dairy 2002 study, which represented 83% of United States dairy operations, identified many potential opportunities for improvement in infectious disease control practices on United States dairies [18]. For example, for operations that brought new cattle onto their farms in 2002, only a quarter required testing for any infectious diseases and only half required some form of vaccination history for new herd additions. Almost half of operations did not separate calves from dams immediately after birth, and pooled colostrum was frequently fed, especially on large (500 or more cattle) operations. Only 5% of operations had any written procedures designed specifically to prevent the introduction and spread of new diseases into their herd, apart from those pertaining to milking procedures [18]. Biosecurity considerations seem particularly relevant in today's industry, where it is not uncommon for expanding dairy operations to introduce new animals into the herd [16,18,19], and heifers are increasingly raised off-site with the potential for contact with animals from other herds [18].

A standard framework, similar to the Hazard Analysis and Critical Control Point programs that are widely applied in food safety, can be applied when designing a biosecurity program [20]. Such a framework typically includes: (1) hazard identification: the specific infectious diseases that could pose a threat are identified and listed in order of their potential impact; (2) exposure assessment: the probable routes by which animals would be exposed to each of the diseases are identified; (3) risk characterization: the level of exposure risk on the individual operation is assessed for each disease and a prioritized list of the most important diseases to be targeted and the areas of greatest exposure risk for those diseases is then produced; and (4) risk management: specific biosecurity and biocontainment protocols for the operation are designed, implemented, and monitored [16]. Protocols are available to assist in herd-level risk characterization for some diseases; for example, the New York State Cattle Health Assurance Program has risk assessment forms for *Salmonella*, Johne's disease, bovine leukemia virus (BLV), and BVDV available for on-farm use by veterinarians (<http://nyschap.vet.cornell.edu/>, accessed 04-Oct-07).

Each individual heifer-rearing operation is unique in infectious disease risks and the potential consequences for that operation. Customized biosecurity and biocontainment protocols need to be developed for each facility, therefore, and tailored for the control of specific diseases. There is no "one-plan-fits-all"; a completely closed herd that is free of Johne's disease may require excellent biosecurity with relatively less emphasis on biocontainment procedures, whereas a heifer-rearing operation that purchases calves from a large number of sources is limited in the biosecurity practices that can be applied and has to rely on biocontainment practices to limit disease. The expanding dairy that rears its own replacements needs both biosecurity

and biocontainment practices to control the introduction and spread of disease. All herds, small and large, are impacted by infectious disease and are likely to benefit from a formal assessment of risks and the preparation and implementation of a biosecurity and biocontainment plan. The goal of this article is to provide an overview of general considerations for biosecurity and biocontainment at each level of the heifer-rearing enterprise. Readers are referred to a recent issue of this series [21] for a more complete overview of biosecurity considerations for the entire herd and the epidemiologic concepts involved in development of a biosecurity plan.

Hazard identification

The pathogens of dairy calves that represent actual or potential hazards vary widely among individual operations. The agents of most frequent concern, and therefore most likely to be considered in the development of biosecurity and biocontainment programs, are discussed below. Diseases that occur in the high-risk preweaning period are emphasized. Other diseases may need to be considered based on herd history, geographic location, primary sources of income that need to be protected, or other herd-specific factors. For example, vesicular stomatitis may need to be considered as a hazard on operations in the southwestern United States, especially those located close to slow-moving water that can harbor potential vectors [22].

The two most prevalent and costly diseases of calves are diarrhea and respiratory disease [3,23–25]. Together they are responsible for more than 80% of mortality in unweaned calves, and respiratory disease is the most important clinical problem in the postweaning period [26,27]. These are complex, multifactorial diseases that are influenced by numerous host, pathogen, and environmental factors. Mixed infections are frequently present in diseased calves [3,28,29]. The causative agents can often be isolated from apparently healthy animals; disease occurs when the right combination of factors interacts to upset the balance between pathogen virulence, exposure level, and host resistance.

The major infectious causes of neonatal calf diarrhea include rotavirus, coronavirus, cryptosporidia, coccidia, various strains of *Escherichia coli*, and *Salmonella* spp [28]. The major infectious causes of respiratory disease in calves are bacterial and include various mycoplasma species, *Pasteurella multocida*, and, less often, *Mannheimia haemolytica* and *Histophilus somni* [30–33]. Bovine respiratory syncytial virus has been associated with outbreaks of dairy calf pneumonia [30,31], but other viral respiratory pathogens seem to play a minor role in respiratory disease in modern calf husbandry systems [3,30,32]. Acute BVDV infection can contribute to morbidity in calves because of its immunosuppressive effects, its ability to potentiate the effects of other pathogens, and, less commonly, its direct pathogenic effects [33–37]. In weaned heifers, another important endemic disease is infectious bovine keratoconjunctivitis (IBK, or pinkeye), caused by *Moraxella*

bovis [38]. With the exception of BVDV, some *Salmonella* species, some mycoplasmal species, and some specific strains of *E coli*, the pathogens responsible for most calthood disease are ubiquitous and are present in a proportion of apparently healthy cattle on most dairy operations [39–45].

There are several pathogens of dairy cattle for which replacement heifers are major reservoirs of infection for the adult herd, and for which maternal/adult cattle-to-neonatal calf transmission or calf-to-calf transmission are important. These include Johne's disease, *Salmonella* spp, BVDV, BLV, and leptospirosis [46–52]. Biosecurity and biocontainment at the calf level are therefore vital components of an overall herd control program for these diseases. For example, a recent study found that biosecurity practices at the calf level were by far the most important and the most economic component of Johne's disease control for midsized United States dairies [8].

In addition to the direct effects caused by infectious diseases of calves, *Cryptosporidium parvum*, *Salmonella* spp, and some strains of *E coli* pose significant zoonotic risks to personnel working with infected calves and, in turn, to their contacts [13–15,53,54]. Young children, the elderly, and the immunocompromised are at highest risk for serious disease. Prevention of transmission of these infectious agents to humans working with calves should be considered in biosecurity and biocontainment protocols.

Exposure assessment

The pathogens that cause neonatal diarrhea and calthood respiratory disease are transmitted predominantly by direct or indirect contact with infected feces or respiratory secretions, respectively. Most of these agents survive well in the environment, allowing for efficient indirect transmission [29,33,55–62]. Given the presence of a particular pathogen on a farm, risk factors for calf morbidity can be divided into those that reduce the ability of the calf to resist disease at a given level of pathogen exposure (eg, failure of passive transfer of maternal antibodies; poor nutritional status; stresses, such as transportation, mixing of calves, or heat and cold stress; mixed infections; and inadequate vaccination programs) and those factors that increase the level of pathogen exposure (eg, poor environmental hygiene, deficiencies in housing design and ventilation, high stocking density, and exposure to other groups of cattle). The current understanding of disease epidemiology is incomplete for many pathogens, thus limiting the veterinarian's ability to fully assess exposure risk. For those cases in which the epidemiology is not well understood, the known risk factors for pathogens with similar transmission dynamics, for undifferentiated disease, or for the same pathogen in a different population can help provide guidance for evaluating exposure risk. For example, the importance of environmental contamination, fomites, or transmission by personnel working with calves in the epidemiology of *Mycoplasma bovis* infection is unknown. We do know, however, that personnel and fomites can be important in the transmission of mycoplasmal

mastitis in the milking parlor, and without additional information it is reasonable to assume that these could also play a role in the calf barn.

Management of the calf and cow at birth has profound effects on the risk of neonatal disease. In many cases, calves become infected with enteric or respiratory pathogens within the first few days of life [45,63–65]. Asymptomatic and subclinically infected cattle shed these pathogens in feces or respiratory secretions and large numbers may be shed by periparturient cows [29,55,66–68]. Neonatal calves often become infected in the maternity area from their dam or other cows by direct contact or exposure to a contaminated environment [55,68–70]. Multiple-cow housing presents a greater opportunity for direct and indirect neonatal contact with infected cows than do individual maternity pens; for example, the risk for *Cryptosporidium* shedding in neonatal calves is higher when they are born in multiple-cow maternity housing compared with individual pens [71]. Maternity areas that are dirty, wet, or dusty increase the risk for calf disease and the risk for periparturient infections in cows [29,72,73]. The length of time after birth that calves remain with their dams affects the risk for pathogen exposure and therefore the risk for neonatal disease [20,29,42]. For example, in one study of 11 dairies in Ontario, calves remaining in the maternity area for more than 1 hour had 39% higher odds of developing diarrhea than calves separated earlier [44].

Failure of passive transfer of maternal immunoglobulin from colostrum is a major risk factor for neonatal diarrhea [29,74–79] and for the incidence and severity of calfhood respiratory disease [40,75,80–85]. Colostrum management is discussed elsewhere in this issue, but the volume, quality, and timing of colostrum feeding are vital for successful passive transfer [86]. Poor hygiene associated with the collection, storage, or feeding of colostrum can increase pathogen exposure and can negatively impact the acquisition of passive immunity [87,88].

Calf-to-calf transmission of enteric and respiratory pathogens occurs by direct or indirect contact. Contaminated environments, feed or water, fomites (eg, equipment), personnel, or mechanical vectors (eg, flies) are often important in disease transmission [29,89]. Calves that have clinical disease typically shed the highest numbers of pathogens and are therefore likely to be the most important reservoirs of infection within the calf facility [29,33]. The housing of susceptible neonates in contact with older preweaned calves or cattle of other age groups increases the risk for pathogen exposure. Virtala and colleagues [85] reported that housing of preweaned calves in the presence of adult cattle increased the risk for calfhood pneumonia, whereas housing in individual hutches was protective.

The type of housing (hutches, individual pens in a barn, group housing), temperature and humidity, bedding substrate (organic, inorganic, pH, moisture content), stocking density, cleaning practices, and manure management all influence the accumulation of pathogens in the housing environment and the survival and replication of pathogens on contaminated surfaces and

bedding. The amount of exposure to direct sunlight greatly influences pathogen survival. In general, appropriately spaced individual calf hutches that are cleaned, disinfected, and moved between successive calves offer the best opportunity for limiting accumulation and calf-to-calf transmission of pathogens [73,86]. For calves housed in a confined airspace, procedures that aerosolize pathogens from dust or feces, such as pressure washing, can increase transmission of enteric pathogens, and inadequate ventilation increases this aerosol transmission [29]. Large numbers of respiratory pathogens can be isolated from the air in barns housing calves that have respiratory disease [3,33,90]. Because reduced airborne bacterial counts in calf pens are associated with a reduced prevalence of respiratory disease, factors that influence airborne bacterial counts, such as pen design, barn ventilation, and stocking density, may affect transmission rates [91]. Independent of effects on bacterial load, poor air quality compromises respiratory defenses, which may increase the risk for disease [3]. Other housing factors associated with a reduced prevalence of respiratory disease in naturally ventilated calf barns in winter include the presence of a solid barrier between each pen and increased ability of the calf to nest [91].

Inadequate cleaning and disinfection of feeding and other equipment on a daily basis, or of housing units between successive calves, increases the environmental load of bacteria and can increase calthood disease [3,92]. Personnel working with calves, including veterinarians, can transmit pathogens to susceptible animals by way of contaminated clothing, boots, and hands [29,33,73]. Milk or colostrum can be contaminated with enteric pathogens if milking hygiene is inadequate, and some agents (eg, *Salmonella*, *Mycoplasma* spp) are shed in milk from infected cows [69,93–95]. Feeding of unpasteurized non-saleable milk has been associated with increased calf morbidity, compared with feeding pasteurized milk [96]. Contaminated feed and water sources can be important in pathogen transmission; in one study of calves in New York dairies, herds where water was obtained from sources other than a well had higher rates of *Cryptosporidium* shedding than herds that used well water [43].

Although the major pathogens involved in neonatal diarrhea or calthood respiratory disease are present on almost all dairy operations, some, such as *Mycoplasma* spp, are less ubiquitous [97]. *Mycoplasma bovis* is believed to be introduced to *M bovis*-free herds by asymptomatic carriers [98–101]. Little is published on the epidemiology of *M bovis* within young calf populations, but there are several potential routes of initial exposure. Calves could become infected from their dams or from other adult cows in the maternity area that are shedding *M bovis* in colostrum, vaginal secretions, or respiratory secretions [60]. The isolation of *M bovis* from vaginal secretions of cows at calving [102,103] and congenital infection of calves [104,105] have been reported, although both events seem to occur infrequently. One of the major means of transmission to young calves is believed to be ingestion of milk from cows shedding *M bovis* from the mammary gland [11,63,69,93,95,103,104].

In fact, exposure to *M bovis*-contaminated milk may be a major means of introduction of this pathogen into previously uninfected calf facilities. Because milk in modern husbandry systems is typically batched for feeding to calves, a single cow shedding *M bovis* can potentially expose a large number of calves to infection, and calves may be repeatedly exposed over the milk-feeding period. The importance of colostrum as a source of *M bovis* infection in calves is not well defined. Whatever the mechanism (infected milk, colostrum, respiratory or vaginal secretions, or congenital infection) by which calves become infected, they may then shed *M bovis* in respiratory secretions and transmit it to other calves by direct or indirect contact. Once established on multiage sites, *M bovis* becomes extremely difficult to eradicate, suggesting that continual transmission from older animals to incoming calves occurs [63,99,106].

The causative agent of infectious bovine keratoconjunctivitis, *Moraxella bovis*, is ubiquitous on North American dairies. Distinct serovars and pilus types of *Moraxella bovis* exist, and new strains can be introduced by exposure to cattle from other herds [38]. The reservoir of infection is asymptomatic carrier cattle that intermittently shed bacteria in respiratory and ocular secretions [38]. The bacteria is highly contagious and transmission occurs by direct contact or, importantly, through mechanical transmission by flies (*Musca autumnalis*, *Musca domestica*, and *Stomoxys calcitrans*) [22,107]. A large number of risk factors for clinical disease have been identified, including environmental factors (eg, dusty conditions and the amount of ultraviolet light exposure), season, the number of flies that visit the eyes of affected cattle, concurrent pathogens, the host immune status (eg, stress such as transportation can precipitate disease outbreaks), and the virulence of the infecting strain [38].

Johne's disease is endemic to North America, and the causative agent, *Mycobacterium avium* subsp. *paratuberculosis* (MAP), is widespread in the dairy population. The NAHMS Dairy 2002 study [108] found that the within-herd apparent prevalence of MAP infection based on fecal culture ranged from 0% to 50% in 62 United States herds. Herd-level prevalence was not estimated, but in an earlier NAHMS study, the apparent prevalence of MAP infection was estimated to be at least 22% of United States dairy herds [109]. Transmission occurs primarily by the fecal-oral route, most importantly to a neonatal calf from its dam or from other infected cows in the maternity area [110,111]. The organism may be shed in colostrum and milk from infected cows, and this can be a route of transmission to calves [110]. Congenital infection occurs occasionally [110]. Susceptibility to infection decreases with age, and young calves are at highest risk for infection. The bacteria can persist for years in the environment and so environmental contamination can be important, especially in the maternity area or other areas to which neonatal calves are exposed [110]. Recent research has suggested that calf-to-calf transmission of MAP may occur when heavily challenged calves are housed in direct contact with naive calves [112], although whether this is important in the epidemiology of Johne's disease has yet to

be determined. A longitudinal study of MAP infection within one herd found that calves co-housed with animals that were later high shedders of the bacteria were at increased risk for infection, also suggesting that calf-to-calf transmission may play a role in Johne's disease epidemiology [111]. Well-established risk factors for MAP infection include (1) introduction of infected cattle into the herd, and (2) practices that increase exposure of young replacement heifers to the pathogen, including failure to remove calves from dams promptly after birth, use of multiple-cow maternity areas, feeding of colostrum and milk from infected cows, and exposure of calves to feces of older cattle [46,113,114]. Cleaning of maternity pens after each use has been associated with reduced herd-level risk for MAP infection [48].

Like Johne's disease, *Salmonella* infection is endemic to North America and seems to be widespread; in one study, seropositive cows were identified on 75% of large dairies in California [115]. In the NAHMS Dairy 2002 study, 30.9% of dairy herds had at least one cow that was fecal culture-positive at a single sampling, and 7.3% of cows sampled were positive [116]. A recent longitudinal study reported a similar prevalence in calves; *Salmonella* was isolated from the feces of 3.8% of calves on 31% of 129 United States dairies [51]. The host-adapted serovar is *S dublin*, but a large number of serovars infect cattle and can cause outbreaks of disease [117].

Salmonella is spread predominantly by direct or indirect contact with feces of infected cattle, and contaminated water and feed are frequently implicated in transmission [73,117–119]. Sick cows are most likely to shed *Salmonella* [120], although subclinically infected cattle can shed large numbers of the bacteria [117]. *Salmonella* spp can also be carried and shed by any species of mammal or bird, and these can be important means of contamination of feed or water [118,119,121]. The bacteria survive in the environment for several months and can replicate under certain conditions of temperature and humidity [29,57,117]. Established risk factors for *Salmonella* infection (fecal shedding) in dairy calves include a high prevalence of fecal shedding in the adult herd and frequent or occasional use of the maternity area as housing for sick cows [51]. Separation of hospital and maternity facilities has been associated with reductions in the prevalence of *Salmonella* spp in herds with endemic infection [52]. The role of antibiotics in *Salmonella* shedding in calves is unclear; routine feeding of medicated milk replacer or milk replacer containing antibiotics was identified as protective for *Salmonella* shedding in two large-scale studies [51,122]. Other investigators identified antibiotic treatment as a risk factor for *Salmonella* shedding in heifers within herds experiencing clinical outbreaks of salmonellosis [123]. In addition to being shed in feces, *Salmonella* can be shed in other body secretions, including nasal secretions, saliva, and milk. Infected saliva and nasal secretions can contribute to transmission by direct contact, aerosols, or contamination of shared feed and water sources [29,124].

BVDV is transmitted vertically (transplacental) and horizontally. When transplacental infection occurs during the first 125 days of gestation, it

can result in the birth of a persistently infected (PI) calf [125]. Transplacental infection occurs when susceptible cows are exposed to BVDV during pregnancy or when a PI cow becomes pregnant [126]. Persistently infected cattle are the most important reservoir of virus; they shed high amounts of virus and are the most efficient sources of horizontal transmission to susceptible cattle [17,126,127]. Infected cattle can shed virus in body fluids, especially saliva, ocular and respiratory secretions, urine, feces, and uterine fluids; horizontal transmission can occur by direct or indirect contact with infected secretions [17,128]. The virus is unlikely to persist for more than a few weeks in the environment [17]. Exposure to fetal fluids from PI calves, and failing to remove calves from maternity barns where PI calves were being born until 2 to 3 hours after birth resulted in infection of susceptible neonates in one study, emphasizing the need for good maternity pen hygiene and rapid removal of calves in BVDV biocontainment programs [128].

The most common risk factor for the introduction of BVDV into a herd is the purchase of pregnant cattle that give birth to PI calves [50]. At the level of calf facility, the most important means of introduction to and transmission within calf facilities is likely to be the presence of PI calves [17,126]. Interventions to reduce the occurrence of PI calves and within-herd biocontainment programs to limit spread of BVDV between age groups are likely to be the most important components of control once BVDV is present in a herd [129]. Before initiating a BVDV control program it is important to determine the current BVDV status of the herd (reviewed in [17]). The BVDV control program can then be targeted to within-herd biocontainment and removal of PI animals or to herd biosecurity as needed. The vaccination status of the resident herd and any introduced cattle influences the herd susceptibility to BVDV infection and should be considered when determining biosecurity and biocontainment priorities.

Infection with BLV can have significant impacts on dairy production and may also affect the marketing of breeding stock, semen, or embryos [130–132]. BLV seems to be widespread in the United States dairy population; the national herd prevalence was estimated at 89% [133]. Herd size, geographic location, and management practices were identified as herd-level risk factors for infection in the NAHMS Dairy 1996 study [133]. BLV transmission generally requires transfer of infected lymphocytes to susceptible cattle, typically by way of blood [134]. A small proportion of infections occur by in utero transmission. BLV is frequently present in colostrum and, to a lesser extent, milk from infected cows, and transmission by these routes has been demonstrated experimentally (reviewed in [134]). Whether colostrum plays a significant role in the epidemiology of infection is not clear, and some studies have not observed any effect of the BLV status of colostrum on the risk for infection in calves [135]. Maternal antibodies seem to protect calves from early infection, and the feeding of unpasteurized milk in BLV-infected herds can increase the risk for infection in calves that do not have passively acquired antibodies to BLV [136,137]. Gouge dehorning has been associated with the horizontal

transmission of BLV when instruments are not cleaned and disinfected between calves [138,139]. Other management procedures that could result in blood transfer between calves if appropriate disinfection was not in place include tail docking, removal of supernumerary teats, castration, insertion of growth implants, tattooing, and ear tagging [134]. Use of shared needles or obstetric sleeves could also potentially transmit infected blood between heifers [134]. Hematophagous flies, including tabanid flies, such as horse and deer flies, and the stable fly (*Stomoxys calcitrans*), may play a role in horizontal transmission of BLV [134].

Leptospirosis is recognized as an important cause of reproductive losses (abortion, infertility, and birth of weak calves) in North American cattle [49,140]. Most infections are caused by the host-adapted serovar *Leptospira borgpetersenii* serovar *hardjo*, although several other non-host-adapted serovars sporadically infect cattle [141]. Chronically infected cattle that shed organisms in urine are the major reservoir of serovar *hardjo* infection in cattle populations [49,142]. For other serovars, maintenance hosts (eg, skunks, opossums, and raccoons) shed the organisms in urine, by which they can contaminate the dairy environment [49]. Infection is widespread; a survey of mature United States cows at slaughter found that 2% were renal carriers and 49% had antibodies to leptospires [141]. Transmission of leptospires on dairies is often indirect, through urine-contaminated environmental sources, such as water. Leptospires survive best in the environment when standing water is present, and infection occurs by invasion through intact oral mucosa or water-saturated skin [49]. Elimination of standing water, controlling wildlife and pests, and implementation of an effective vaccination program are the major means of reducing risk from leptospirosis on dairies [49]. Leptospires are zoonotic and farm workers can become infected through direct or indirect contact with infected animals or their urine [143].

Risk characterization

During risk characterization the level of exposure risk on the individual enterprise is evaluated for each potential hazard. Diagnostic testing may be indicated to determine the status of infection with particular pathogens (eg, MAP, BVDV, BLV), if this is unknown. Current morbidity and mortality data and calf performance data should be examined to identify areas of special concern.

Several qualitative approaches to evaluate risk for some of the specific agents of concern to heifer-rearing operations have been described. A risk assessment of Johne's disease transmission has been described for on-farm use by veterinarians (available at <http://www.jd-rom.com/riskassessment.asp> accessed 04-Oct-07; reviewed in [73]). The New York State Cattle Health Assurance Program produces forms for risk assessment of *Salmonella*, Johne's disease, BLV, and BVDV for on-farm use by veterinarians (available at <http://nyschap.vet.cornell.edu/>, accessed 04-Oct-07). Although these

are whole-herd risk assessments, they include assessment of maternity pen and heifer management and they can be expanded to include a comprehensive review of factors that affect pathogen exposure and disease resistance in dairy calves. Areas that should be included are the management of purchased animals or replacements returning from off-site locations; maternity barn management; colostrum management; housing of calves and environmental hygiene; milk feeding practices; feed and water management; practices that could increase the risk for pathogen transmission by fomites, vehicles, and personnel; vector control; vaccination programs; record keeping; monitoring of disease and performance data; and the use of written biosecurity and biocontainment protocols.

Following review of the risk for potential hazards, a customized list of priorities for biosecurity and biocontainment can be produced and used for the development of risk-management practices. Cost-benefit considerations are important before instituting control programs for any disease. For example, although eradication of BLV through testing and culling may be possible, the institution of management practices to prevent transmission of infection is likely to be the most economically acceptable control strategy for most commercial dairy herds [130].

Risk management: biosecurity for heifer facilities

For most dairy farms, the greatest risk to biosecurity is the introduction of new animals. On-farm preventive practices used in biosecurity programs include screening of new animals, testing source herds, quarantine post-arrival, preventive treatments, and vaccination [73]. In the United States, nearly half of dairy operations bring in new animals each year [18]. These high-risk cattle include purchased additions, repossessed additions, owned cattle but new to property, or cattle returning from a show or fair. From the calf raiser's perspective, most, if not all, animals on the farms fall in the high-risk category. Additional sources of disease risk in replacement operations include direct or indirect contact with adult animals.

Biosecurity data from several publications indicate that less than 50% of expansion dairies purchase additions from known sources [19,144], less than 50% of dairy operations require health testing of new additions [18,19], and less than 50% of expansion dairies segregate or quarantine new additions [19]. In one citing from Michigan dairy herds undergoing expansion, 6% and 15% of herds segregated new cows and heifers, respectively [144]. Faust and colleagues [19] also reported that less than 20% of dairies have knowledge of source and quarantine post-arrival.

The NAHMS 2002 publication indicates that dairy managers may be more aware of the biosecurity needs of the replacement herd [18]. In that report, 79%, 36%, and 27% of dairy operations reported that they had quarantine programs in place for animals brought in as unweaned calves, non-bred heifers, and pregnant heifers, respectively. More than 75% of

operations did not require screening for infectious diseases before purchase, however.

A partial and incomplete list of diseases that have the potential to be introduced to dairy replacement or commercial dairy calf/heifer operations is presented in Table 1. The heading “Time to disease occurrence” is an important factor in determining the methods of control; those that have short time to occurrence intervals are more amenable to control by segregation and quarantine. Other noninfectious health problems associated with additions to a dairy include digestive upset caused by feed change, injuries from transportation, unfamiliar facilities, stall design, or change in herd social order.

Managing health risks when introducing animals to a dairy replacement operation should include three areas:

- control strategies before purchase
- post-purchase management of animals
- management of the resident herd

Control strategies before purchase

When considering acquiring animals, farm management should assess any and all potential risks before purchase (Box 1). First, one should consider the health, management, and immune status of the resident herd. Are they sufficiently immune, or do they have a high capacity for immune function to weather the changes inherent with new additions? Also, consider the disease/exposure and immune status of the incoming animals. Anticipate and develop strategies to prevent, identify, and control problems before they occur. Finally, compare costs of preventive measures to the cost of potential disease (treatment cost, culling, impact on future resident herd performance and production).

In an ideal situation, 4 to 6 weeks before delivery of additions the health history of individuals and the herd of origin should be taken. On-site inspection and health procedures should be used at this time (pregnancy check, primary vaccination, parasite control). Two to 3 weeks before movement, booster vaccines should be given if necessary. For the producer receiving

Table 1
Potential disease threats from brought-in animals to dairy replacement or commercial calf/heifer-rearing operations

Disease condition	Time to occurrence post-arrival
Bovine respiratory disease complex	1–4 wk
Salmonellosis—acute illness or chronic carrier	Days to months
Infectious abortion	Days to months
Bovine viral diarrhea	1 wk to months
Foot rot/heel warts—lameness, decreased production	Weeks to months
Johne’s disease	Months to years
Bovine leukemia virus	Months to years

Box 1. Biosecurity practices for newly purchased young stock

- Whenever possible purchase cattle for which vaccination and herd health histories are available
- Maximize the ability of the resident herd to resist infection
 - Use an appropriate customized vaccination program
 - Address deficiencies in nutrition, housing, and overall health of the resident herd
- Minimize stress during transportation and processing
- Transport new additions in the farm's own vehicle. Clean and disinfect the vehicle before and after transportation.
- On the day of arrival
 - Identify the animals; are they what was purchased? Do they have permanent, easily readable identification?
 - Process all new animals through a footbath
 - Do not vaccinated for 5 to 7 days (exception intranasal IBR/PI₃ and possibly oral coronavirus vaccines)
 - ± deworm (depending on age) and treat for ectoparasites
 - ± inspect udders (depending on age)
 - Consider antibiotic metaphylaxis for high-risk cattle
- Quarantine new additions for a minimum of 30 days
 - Strictly control traffic and personnel in the quarantine area
 - Closely monitor the health of new additions during quarantine and investigate unusual health events
- All new purchases should be tested for BVDV infection status
- Consider testing for other diseases based on herd status, disease epidemiology, age of purchased cattle, and knowledge of source herd health history (eg, BLV, *Mycoplasma* spp)
- Monitor new purchases for contagious mastitis pathogens at first calving
- Record health data and monitor it regularly so that problems are recognized quickly

animals back from a commercial heifer raiser, these control points are often built into contracts with the raiser. Depending on the resident herd's health status, other testing might include BVDV-PI, Johne's disease, BLV, and so forth (see [Box 1](#); [Box 2](#)). Because of cost and limitations in test sensitivity, testing alone may not eliminate the risk for purchasing diseased animals. Post-purchase management of incoming animals and management of the home herd are therefore important control points.

The influence of knowledge of the herd of origin is of ultimate importance when trying to minimize disease risk in incoming animals. Consider the following situation in which a dairy has the option to purchase

Box 2. Practices to minimize the introduction of pathogens to the resident herd by replacement heifers

- Maximize the ability of the resident herd to resist infection
 - Use an appropriate customized vaccination program
 - Address deficiencies in nutrition, housing, and overall health
- If heifers are raised off-site
 - Consider cost–benefit of a contract heifer grower who will keep your heifers separate from those of other herds
 - Know the biocontainment practices of the grower
 - Quarantine returning heifers for at least 30 days
 - Consider monitoring the BVDV status of returning heifers before introduction into the resident herd
- Limit the introduction of contagious mastitic pathogens by individual milk culture of heifers at calving
- Use appropriate endo- and ectoparasite control in heifers to limit the introduction of parasites into the resident herd

2-year-old replacements from two sources of varying MAP prevalence. Herd X has a historic high prevalence (30%) of MAP-positive cows, whereas Herd Y has a historic low prevalence (5%). If you are going to use MAP ELISA for your prepurchase screening of individual animals (test characteristics are the same in each herd; sensitivity = 50%, specificity = 99.5%) then this is what you will see from testing animals from each herd:

Herd X, n = 400 cows				Herd Y, n = 400 cows			
	D+	D–		T+	D+	D–	
T+	60	2	62	T+	10	2	12
T–	60	278	338	T–	10	378	388
	120	280	400		20	380	400

Negative predictive value: Herd X = $278/338 = 82\%$, Herd Y = $378/388 = 97\%$.
Abbreviations: D, true disease status; T, test result.

What you as a veterinarian are interested in are test-negative cattle (boldface entries). In Herd X there are 338 test-negative; in Herd Y, 388 are test-negative. In neither case did your testing program greatly improve the risk for receiving diseased animals, however. Without testing, you would expect 70% and 95% of animals to be nondiseased in Herds X and Y, respectively. With testing, you improved the proportion of nondiseased to 82% and 97%, respectively. The knowledge of herd history had a more significant impact on the proportion nondiseased than did testing. If source herd health information is unknown, testing decreases the prevalence of MAP-positive animals entering the herd.

There are multiple options as sources for herd replacements. A single source purchase from a reputable herd with extra replacements to sell has the advantage of known herd history and animals can be inspected (and selected) before purchase. A disadvantage is that these animals are likely more expensive. A multiple-source purchase from a cattle dealer allows the buyer to select heifers, which usually have less disease risk than mature cows; however, herd-of-origin health history is usually unknown. The least desirable source for purchased animals is the sale barn.

Livestock transport vehicles may be an additional biosecurity risk for the resident herd. It is highly encouraged to never allow a livestock transport vehicle onto the farm proper. Use peripheral unloading and holding pens for pickups and deliveries. Reputable transport companies with experience in livestock hauling use only clean well-bedded trucks to move cattle, thereby reducing injuries during transport and introduction of disease from manure on the truck.

Few studies on the effect of transportation on shedding of pathogenic bacteria are available. One such study done in beef cattle investigated the prevalence of *E coli* O157 and *Salmonella* spp before and after transportation to a slaughter facility [145]. Fecal prevalence of *Salmonella* spp increased from 18% at the feed yard to 89% 6 hours later at the packing house. Average prevalence for *Salmonella* spp on the trailers after arrival at the packing house was 59%. These results demonstrated that transportation may be a potential stressor for cattle, as evidenced by the increased shedding of *Salmonella* spp.

Postpurchase management of animals

A minimum checklist on the day of arrival is presented in **Box 1**. Whenever possible, new arrivals should be segregated or quarantined. Quarantine is most effective for diseases with short incubation periods and readily definable, overt clinical signs. The duration of quarantine should be of sufficient length to allow risk periods for respiratory and digestive diseases to pass; this has generally been recommended to be 21 to 30 days. The quarantine facility should be separate from the resident herd with a minimum separation of 30 feet. Housing should be clean and comfortable with good ventilation, and water sources should not be shared with resident herd animals. The facility should be designed so that routine health monitoring is easily done, a safe transition ration can be fed, and group health management procedures can be performed easily (booster vaccine, group foot treatment, inspection and treatment of any sick animals).

It is helpful if you plan in advance for any disastrous health events. Identify and train staff, create written protocols, and have aggressive monitoring in place. A post-arrival testing scheme may be warranted (BVDV, John's disease, BLV). A plan for management of sick animals must be in place and should include isolation of sick animals, decisions regarding treatment

or culling, treatment records, and some method to evaluate successes and failures.

Management of the resident herd

An often neglected area of consideration when managing the purchase of cattle is the resident herd. One should focus on optimizing disease resistance and immune function of the resident herd. This focus requires a history, a plan, and healthy animals that are able to respond to disease challenge. Immunizations can be an effective tool in disease management; however, they should not be relied on to be the sole disease management plan. A sound nutrition program that supports good overall health, an environment that minimizes stress, and facilities that maximize animal comfort and welfare are important in promoting innate disease resistance. Animals managed to this level of care respond better to vaccination and therapy when warranted [146].

Risk management: biocontainment for heifer facilities

The goals of biocontainment are to limit spread of infectious disease agents within a facility and to prevent spread to other groups of cattle outside of the facility. Even endemic diseases can be limited by good biocontainment practices.

Maternity pen management

Maternity areas are one of the highest-risk environments for pathogen transmission to susceptible calves and are therefore one of the most important areas for environmental hygiene (Box 3). Highest priority should be given to keeping the maternity area clean, dry, and well bedded. From a biocontainment perspective, well-managed, adequately sized individual maternity pens that are cleaned and disinfected after each calving are preferable to multiple-cow housing systems. The use of individual pens minimizes the environmental build-up of pathogens and limits the number of adult cows (each a potential shedder of pathogens) with which neonates have direct or indirect contact. Successful management of individual maternity pens is labor intensive, however, requiring frequent monitoring of periparturient cows and moving them up to pens as calving approaches. After each calving, pens must be thoroughly cleaned and disinfected before being freshly bedded. Although multiple-cow bedded packs are commonly used as an alternative to labor-intensive individual pens, keeping these areas clean and dry can be difficult and requires frequent replacement of the top layer of bedding [73]. Regardless of the type of housing used, the focus should be on providing the cleanest and driest environment possible. Maternity facilities should ideally be separated from housing for other cattle groups and

Box 3. Practices to keep diseases from entering calf facilities on dairies that rear their own replacements

- Have a formal quarantine, disease testing, and monitoring program in place for any purchased cattle (all age groups)
- Remove calves from the maternity area as soon as possible
- Reduce pathogen load in the maternity area
 - Clean, dry bedding
 - Never use the maternity area to house sick cows or as a quarantine area
 - Individual pens are preferable to multiple-cow housing
- Prevent pathogen exposure during transportation of neonatal calves
 - Reserve a vehicle specifically for this use and never use this vehicle to transport sick or stillborn calves
 - Clean and disinfect the vehicle after each use
- Prevent pathogen exposure in colostrum
 - Do not use colostrum from high-risk (eg, Johne-positive) cows
 - Use good milking hygiene to prevent contamination of colostrum
 - Do not pool colostrum
 - Freeze colostrum to reduce BLV transmission and do not feed if bloody
 - Consider pasteurization
- Prevent pathogen exposure in milk by pasteurization of whole (bulk tank or non-saleable) milk or feeding a high-quality milk replacer
- Minimize direct and indirect contact with other age groups of cattle
 - Locate calf facilities away from other age groups
 - Do not use feed, bedding, or water that may be contaminated with feces, urine, or pen run-off from other age groups
- Prevent introduction of pathogens by equipment, fomites, and personnel
 - Handle and feed susceptible neonates before other cattle
 - Personnel who have been working with other cattle should change into clean outer clothing and clean and disinfect boots and hands before entering calf facilities, and should wear gloves when handling calves. Provide clothing and boots for visitors.
 - Use footbaths for entering and leaving the calf facility
 - Limit vehicle and personnel traffic around the calf facility

Limit movement of equipment from other areas of the farm, or other farms, to the calf facility, and clean and disinfect all equipment before introduction

- Control vectors that could introduce disease (flies, rodents, birds, and so forth)
- Consider screening to identify calves persistently infected with BVDV
- Record health data and monitor it regularly

should be designed or modified to minimize pathogen accumulation by providing excellent ventilation, excellent drainage, and ease of cleaning and sanitation. In addition, facilities should provide adequate lighting, ease of observation, and ease of movement of cattle by one person to maximize compliance with biocontainment practices.

Cows that are suspected to be particularly high risks for disease transmission can be identified before calving (eg, cows known to be infected with MAP or *Mycoplasma bovis*, or newly purchased cattle of unknown health status). These cows could potentially be housed in a separate calving area. Cattle groups that are often associated with high rates of pathogen shedding include sick cows and cull cows [73,120]; maternity facilities should never be used to house cows that are sick, waiting to be culled, or in quarantine, and should be located in a physically separate area of the farm to these areas.

Management of the calf at birth

One of the most important factors influencing the risk for exposure to many neonatal pathogens and Johne's disease is the length of time that calves remain in the maternity area [20,26,29,42,44,147]. Despite this, data from the 2002 NAHMS study showed that only 52.9% of dairy operations separated calves from dams immediately after birth and did not allow nursing, whereas 22.2% allowed calves to suckle but removed them before 12 hours of age, 15.9% removed calves between 12 and 24 hours, and 8.7% removed calves sometime after 24 hours [18]. The longer the cow-calf interaction, the greater the chance for pathogen transmission by way of feces, respiratory secretions, a contaminated environment, or ingestion of colostrum that contains pathogens. Udder-seeking behavior is likely to increase pathogen exposure, and so removal of the calf before standing is desirable. Although labor intensive, removal of the calf immediately after birth should be a cornerstone of biocontainment in herds where control of neonatal calf diarrhea, calfhood respiratory disease, or Johne's disease have been identified as priorities.

After removal from the maternity pen, calves should be processed immediately (ear tagged, fed colostrum, and so on) and quickly moved to the calf facility or, in cold conditions, to a calf-warming box to dry before moving

into the calf housing. Transportation equipment should be reserved exclusively for newborn calves and never used to move sick calves, stillborn calves, or cattle of other age groups. Staff should be educated that the calf is extremely vulnerable to infection until it has absorbed antibodies from colostrum and that excellent hygiene is required when working with neonates. Special attention should be given to thorough cleaning and disinfection of nipples, bottles, tube feeders, and other equipment, and vehicles, holding pens, and warming boxes after each use.

A good colostrum feeding program to ensure successful passive transfer is crucial to maximize the ability of neonatal calves to resist disease; this has been recently reviewed [148] and is also discussed elsewhere in this issue. Clean udders (clipped before calving, clean and dry maternity area) and good milking hygiene during colostrum collection are important to prevent contamination with pathogens, especially those spread by the fecal–oral route. Pooling of colostrum should be avoided unless it is to be pasteurized, because it increases risk for exposure to pathogens. In some situations it may be advantageous to avoid feeding colostrum from high-risk cows. For example, in herds infected with MAP, only colostrum from low-risk cows (test-negative, no clinical signs of disease) or pasteurized colostrum should be fed [149]. For the control of BLV, feeding of colostrum from seronegative cows in herds of low BLV prevalence, or freezing of all colostrum in higher prevalence herds is recommended; freezing kills leukocytes and therefore reduces the chance of BLV transmission [47]. Bloody or mastitic colostrum should not be fed. Pathogen-specific colostrum antibody titers and neonatal protection against some infectious agents can be enhanced by proper vaccination of cows during late gestation [150–152].

Data from the NAHMS Dairy 2002 study showed that despite the increased risk of using pooled colostrum, of those operations that normally hand-fed colostrum (rather than letting calves suckle the dam), 70.6% of large (500 cows or more), 37.4% of medium (100–499 cows), and 22.1% of small (<100 cows) dairy operations fed pooled colostrum [18]. There is therefore substantial opportunity to improve colostrum practices on United States dairies for effective biocontainment. Producers should consider pasteurization of colostrum, especially in herds in which control of Johne's disease, *Mycoplasma bovis*, and *Salmonella* infections are identified as priorities; readers are referred to the chapter on colostrum management in this issue for discussion of pasteurization. Although colostrum substitutes may not provide an equivalent level of passive transfer as does feeding whole colostrum [153–155], their use may be indicated when clean colostrum from disease-free cows is not available.

Calf housing

To minimize direct or indirect contact with older cattle, heifer-rearing facilities should be physically separated from other animal groups

(Boxes 4 and 5). Likewise, pre- and postweaning facilities should be physically separate from each other. Separate hospital and, possibly, quarantine areas should be established for pre- and postweaning calves. All calf facilities should be accessible by foot and road without transit through areas housing older cattle. Facilities need to be sited in well-drained areas where there is no run-off from other animal housing or access to a water source with the potential for contamination by other cattle groups or wildlife. The NAHMS Dairy 2002 study found that 22.8% of operations permitted physical (nose-to-nose) contact of unweaned calves with weaned calves not yet of breeding age, 13.3% of operations permitted contact with bred heifers, and 15.4% of operations permitted contact with adult cattle [18]. Design or modification of housing facilities to eliminate such contacts is important for effective biocontainment. Other considerations for calf housing are discussed elsewhere in this issue, and requirements for ventilation of calf housing have been reviewed [33].

Calves should be housed individually until after weaning to minimize between-calf transmission by infected respiratory secretions or feces. Individual hutches present the least opportunity for pathogen transmission when managed appropriately, because animal density is lower than that in barns, air space is not confined, and hutches can be moved to fresh ground between calves to minimize pathogen accumulation. Plastic or fiberglass hutches are easier to clean and disinfect effectively than wooden hutches [29]. Hutches should be situated at least 4 ft apart on well-drained, elevated ground, and bedding should be kept clean and dry. Between successive calves hutches should be scrubbed, pressure washed, and disinfected or steam-cleaned. Hutches should then be moved to fresh ground to avoid environmental build-up of pathogens and to allow inactivation of pathogens by ultraviolet light exposure [73].

Barns should be designed or modified to provide sufficient airspace per calf at the maximum stocking density and ease of cleaning and waste removal to maximize compliance with biocontainment programs. Ideally, individual pens in barns should be designed to prevent nose-to-nose and fecal contact between neighboring calves [33]. Solid barriers between pens can negatively impact air flow, however. Solid side-walls with open fronts and backs facilitated pen ventilation while minimizing respiratory disease in one study [91]. Factors that impact pen-level air quality, including stocking density, barn ventilation, bedding management, and pen design, should be assessed and deficiencies addressed. Providing suitable nesting material (eg, deep straw) when environmental temperatures fall below the thermo-neutral zone of the calf is preferable to reducing barn ventilation for the prevention of respiratory disease [91]. Recycled flush water from adult cow facilities should not be used for flushing calf facilities [20].

Postweaning, calves should be moved into small group pens or hutches with fewer than 10 calves per group (Box 6) [156–158]. Keeping group sizes small minimizes the risk for exposure to infectious agents from carrier animals or environmental contamination for any given calf during the high-risk

Box 4. Practices to keep diseases from entering off-site heifer-rearing facilities

- Understand disease risks posed by each source farm
Discuss which diseases are present and the biosecurity and biocontainment practices in place on that farm
- Consider rejecting calves from high-risk farms, or quarantining them on arrival
- Consider grouping heifers by farm of origin
- Prevent pathogen exposure during transportation of incoming heifers
Use your own vehicle; clean and disinfect it after every use
The vehicle should be specifically reserved for this use; do not use to transport sick calves or other age groups of cattle
Minimize heat, cold, and overcrowding stress during transportation
- Prevent pathogen exposure in milk by pasteurization of whole (bulk tank or non-saleable) milk or feeding a high-quality milk replacer
- Minimize direct and indirect contact with other age groups of cattle
Locate calf facilities away from other cattle
Do not use feed, bedding, or water that may be contaminated with feces, urine, or pen run-off from other cattle
- Prevent introduction of pathogens by equipment, fomites, and personnel
Handle and feed susceptible neonates before other cattle
Personnel that have been working with other cattle or have visited other farms should change into clean outer clothing, clean and disinfect boots and hands before entering calf facilities, and wear gloves when handling calves. Provide clothing and boots for visitors.
Use footbaths for entering and leaving the calf facility
Limit vehicle and personnel traffic around the calf facility
Limit access by vehicles that have visited other farms; they should be cleaned and disinfected before entry onto the farm
Limit movement of equipment from other areas of the farm or other farms to the calf facility, and clean and disinfect all equipment before introduction
- Control vectors that could introduce disease (flies, rodents, birds, and so forth)
- Screen calves to identify those persistently infected with BVDV

Box 5. Biocontainment practices for individual calf housing

- Maximize ability of the calf to resist infection
 - Address deficiencies in colostrum management
 - Consider vaccination of cows to increase the concentration of specific antibody in colostrum
 - Minimize stress caused by environmental extremes and handling
 - Address deficiencies in nutrition
 - Have an appropriate vaccination program in place
- Minimize direct contact between incoming neonates and older calves
 - Use “all in—all out” practices whenever possible
 - Space individual calf hutches appropriately
- Minimize pathogen build-up in the environment
 - Provide adequate ventilation
 - Use good environmental hygiene and manure management
 - Avoid overcrowding
 - Move hutches frequently
- Prevent indirect transmission of pathogens by fomites
 - Implement formal protocols for the cleaning, disinfection, and drying of buckets, stalls, or hutches, and all other equipment for within the housing period and between successive calves
 - Use electric rather than gouge dehorning
 - Change needles after each calf when giving injections
- Control vectors that can spread pathogens (flies, rodents, birds, and so forth)
- Prevent indirect transmission by personnel
 - Handle calves from youngest to oldest, and sick calves last
 - If possible, have separate people handle sick calves and incoming neonates
 - Wear gloves to assist calves to nurse and to handle sick calves; change after each calf
 - Clean and disinfect hands and boots after handling sick calves and when moving between sections of the calf facility
 - Have gloves, hoses, scrub brushes, and footbaths available for use when entering and leaving each section of the calf facility, and maintain them properly
- Consider removal, isolation, or strategic treatment of high-risk calves (eg, very premature calves) or groups of calves (eg, calves that have been exposed to unusually extreme environmental conditions)

- During disease outbreaks, assume all calves in the affected section of the calf facility are infected
Have stringent biocontainment protocols prepared for disease outbreak situations and institute them immediately when a problem is recognized
- Record health data and monitor it regularly so that problems are recognized quickly

postweaning period [159]. As for preweaned calves, ventilation, stocking density, and ease of cleaning, feeding, and waste removal are crucial considerations in facility design. Calf-handling facilities (eg, headlocks) should be present in each pen or designed so that calves can be moved easily to and from pens without direct contact with other calf groups. Outdoor pens should be sited in well-drained areas. If heifers are reared off-site, consider using a contract grower who can separate heifers based on herd to avoid exposure to pathogens from other herds. Strict adherence to biocontainment procedures during transportation and at the heifer facility is necessary to maintain effective isolation of animals from separate herds.

Whenever possible, producers should look for facility design or animal-flow options that allow “all in—all out” management of heifers [73]. This management minimizes the opportunity for direct and indirect contact between infected and susceptible calves and maximizes the ability to break transmission cycles by thoroughly cleaning and disinfecting the facility between batches of calves. Movement of calves should always be unidirectional; that is, calves should never be moved back from an area housing older calves to an area housing younger calves [20]. If animals have to be removed from a group because of injury, ill thrift, or chronic disease, they should be housed in a hospital area that is specific for postweaned calves. Some authors have recommended that if these calves are to be returned to their cohort they should be quarantined for at least 21 days after removal from the hospital pens [160].

Vaccination and other preventative health interventions

Vaccination is an important means of improving herd immunity. By reducing the number of susceptible calves in the population, vaccination reduces the risk for spread of endemic pathogens and reduces the risk for a disease outbreak after a new pathogen is introduced [20]. Because each calf-rearing facility is unique in the important diseases to be targeted, customized vaccination programs must be developed for each facility. For effective disease control, vaccines given before weaning should be timed so that protective immunity is in place when heifers are moved into group housing or off-site. Likewise, for replacements returning to the resident

Box 6. Biocontainment practices for postweaning group housing

- Maximize ability of the calf to resist infection
 - Minimize stress caused by environmental extremes and handling
 - Address deficiencies in nutrition
 - Implement an appropriate preventative health program, including vaccination and strategic use of medications, such as coccidiostats
- Minimize risk for exposure by keeping group sizes small, and design or modify pens to prevent direct contact between groups
- Use “all in—all out” practices
- Have a separate housing area for sick or injured calves that need to be removed from groups; never move calves back to facilities housing younger animals
- Minimize pathogen build-up in the environment
 - Avoid overcrowding
 - If group hutches are used, move frequently
 - Use good environmental hygiene and manure management
 - Modify pens to eliminate standing water
- Minimize direct and indirect contact with other cattle
 - Locate heifer facilities away from other age groups
 - Do not use feed, bedding, or water that may be contaminated with saliva, feces, urine, or pen run-off from other age groups
- Minimize transmission of pathogens by fomites
 - Implement formal protocols for cleaning, disinfection, and drying of feeding equipment, waterers, and all other equipment within the housing period and between successive groups
 - Change needles after each calf when giving injections
 - Disinfect all equipment that may become blood contaminated (eg, tattooing equipment) after each animal
- Control vectors that can spread pathogens (flies, rodents, birds, and so forth)
- Prevent indirect transmission by personnel
 - Handle groups from youngest to oldest, and sick calves last
 - Clean and disinfect hands and boots when moving between age groups and after handling each sick calf
- During disease outbreaks, assume all calves in the group and any in-contact groups are infected

Have stringent biocontainment protocols prepared for disease outbreak situations and institute them immediately when a problem is recognized

- Record health data and monitor it regularly so that problems are recognized quickly

herd, vaccination should be timed so that protective immunity is in place before animals are transported. General vaccination recommendations for replacement heifers are reviewed elsewhere in this issue.

For herds in which coccidiosis is a problem, the use of coccidiostats in rations of at-risk heifer groups reduces clinical disease and shedding, thus reducing the level of environmental exposure to these pathogens [161]. Inclusion of monensin in postweaning heifer rations has also been associated with reduced in-herd prevalence of *Salmonella* infection [162]. Readers are referred to the chapter on preventative health in this issue for further discussion of coccidiostats and feed additives. Strategic metaphylactic use of antibiotics during disease outbreaks or in high-risk heifer groups can be an effective method for reducing the impact of infectious disease and should be considered on an individual herd basis.

To limit BVDV exposure, producers should consider testing incoming calves to detect animals that are PI, particularly when undergoing herd expansion or when heifers are raised off-site [17,50,159]. If all calves are not tested, then strategic testing should include the calves of all new herd additions. Testing as soon as possible after birth allows early removal of PI calves and helps limit transmission of infection to susceptible calves.

Preventing pathogen exposure in milk, feed, and water

Exposure to pathogens that can be shed in the milk of infected cows (eg, *Mycoplasma* spp, MAP, *Salmonella* spp) can be reduced by feeding milk replacer or by on-farm pasteurization of bulk-tank or waste-milk before feeding [95,163]. From a biocontainment perspective the feeding of unpasteurized waste-milk is a high-risk practice and should be avoided. Pasteurization of waste-milk has also been associated with improved calf performance compared with feeding unpasteurized milk [96,164]. Considerations for the successful on-farm pasteurization of waste-milk are discussed elsewhere in this issue.

In individual calf housing, milk-handling equipment and buckets should be cleaned and disinfected daily. Nipples, bottles, and tube-feeders should be cleaned, disinfected, and allowed to dry after each use. Buckets used for starter feed or water and automatic waterers should be thoroughly cleaned, disinfected, and allowed to dry between calves. General cleaning and disinfection considerations for cattle facilities have been reviewed

[29,165], and should include scrubbing and detergents to remove organic material followed by an appropriate disinfectant.

Manure-handling equipment should not be used to handle feed [20]. Despite the potential for pathogen transmission associated with this practice, the NAHMS Dairy 2002 study found that 58.8% of operations used the same equipment to handle feedstuffs and manure, and of these, 15.5% had no cleaning or disinfection procedures for equipment after handling manure [18]. If feed-handling equipment must be shared between cattle groups it should be thoroughly cleaned and, if possible, disinfected before entering heifer-rearing areas.

In postweaning housing, feeding areas and water sources should be designed to minimize the potential for manure contamination, and feed bunks should be cleaned daily. Feed that could potentially be contaminated with feces, urine, or saliva of older cattle should not be fed to heifers. If feed refusals are used they should be fed to the oldest heifer groups only, and a rigorous vaccination program should be in place to help maximize immunity to common enteric and respiratory pathogens that could be transmitted by this practice [20,166]. Heifers should not be fed forages harvested the same season that adult-cow manure was spread on the field, and adult-cow manure should not be spread on pastures where heifers are grazed [73,167]. Feedstuffs can become contaminated with *Salmonella* spp and other pathogens by way of the feces of other species, such as rodents and birds, and by mechanical vectors, such as flies [73,166]; control programs for these pests should be used in feed-storage and calf-housing areas, and concentrates should be stored in an enclosed building. Automatic waterers and water troughs should be cleaned and disinfected regularly. Access to water sources (eg, creeks, ponds) that may be contaminated by cattle, wildlife, or pen run-off should be prevented [166].

Vector control

Other animate vectors, including flies, rodents, birds, cats, dogs, deer, and other wildlife, can transmit many of the pathogens of concern in dairy heifer production. Transmission may be simply mechanical (eg, flies transmitting *Moraxella bovis* and neonatal enteric pathogens) or can involve contact between other infected host species and susceptible calves or their feedstuffs (eg, birds infected with *Salmonella* spp) [20,29]. Bird, rodent, and fly control programs should be implemented for all calf facilities [20,22,73]. Consistent removal of decaying organic matter, including manure, old hay or straw, and spoiled feed and silage, from the general area around calf facilities is an important component of vector (especially fly) control [22,29].

Limiting pathogen transmission by equipment and personnel

Anything that comes in contact with an infected animal, feces, or other secretions can act as a fomite for transmission of pathogens; this includes

equipment, transport vehicles, and personnel. Vehicles used on other areas of the farm, especially those that may have contacted manure of other cattle groups, should be cleaned before entering calf facilities. All equipment used for handling calves should be cleaned and disinfected between uses. Strategies that prevent blood-contaminated fomites should be used to reduce BLV transmission; recommended minimal control practices for BLV include the use of individual disposable needles and individual obstetric sleeves, the washing and disinfection of instruments that may be blood-contaminated after each animal (eg, obstetric equipment, tattoo pliers, hoof knives), and use of electric rather than gouge dehorers [130,132,134].

Practices that minimize the transmission of infectious disease agents by staff should be implemented. On larger farms, specific people should be designated for the removal of calves from the maternity area and colostrum feeding. These people should not handle cattle of other groups or should change into clean outer clothing or coveralls before entering the maternity area. Hands and boots should be cleaned and disinfected before handling each newborn calf. If the same person is responsible for handling cows and calves in the maternity area, the calf should be handled first. Footbaths should be used to enter and leave maternity areas, each section of calf housing, and hospital facilities. In calf facilities, staff should always work with the youngest, most susceptible calves first. Sick calves should be handled last; if possible, have separate people handle sick calves and neonates. After handling sick calves, hands and boots should be thoroughly washed and disinfected; ideally, separate outer clothing should be worn in the calf hospital area. Gloves should always be worn to assist calves to nurse and to handle sick calves, and these should be changed after each calf. During a disease outbreak, it is important to consider all animals in the group or facility as potential sources of infection, not just those that are clinically ill.

It is important to make it as easy as possible for employees to follow good biocontainment practices. Stations for hand and boot washing and for obtaining clean gloves should be convenient to the work site. Brushes and hoses need to be in good working order and hoses must have enough water pressure to wash effectively. Proper use of footbaths is necessary if they are to be effective. Boots should be rinsed off before using the footbath because inorganic material inactivates disinfectants. Footbaths need to be inspected and changed at least daily and as often if necessary to keep them clean (often several times a day) [18].

Traffic of people from other areas and from outside the farm into the maternity area and calf facilities should be tightly controlled. Visitors should wear disposable foot covers or clean boots and coveralls provided by the farm, and should not contact animals. From the NAHMS Dairy 2002 study, 38.6% of operations had guidelines to determine which visitors were allowed to visit animal areas. Only 13.5% had a “no visitor” policy and few operations provided footbaths (5.4%) or clean or disposable boots (16.3%) for visitors [18]. Veterinarians should arrive at the calf facilities

wearing clean coveralls and should disinfect boots between areas of the farm. Personnel that need to access multiple areas of the dairy (eg, owners, veterinarians, and consultants) should always visit the calf facilities first, and visit the maternity area before working with other adult cow groups.

Monitoring and review of health data

Herd health data, including treatment and death rates for individual diseases and test results, need to be effectively recorded in a way that allows easy access and manipulation for analyses. Herd health and performance data should be reviewed regularly for early identification of potential disease problems. Producers should be aware of the need to discuss any unusual health events (eg, unusual clinical signs, increased incidence of clinical disease, reduced performance, or potential biosecurity lapses) with their veterinarian. Biosecurity and biocontainment protocols should be reviewed regularly and adjustments made as priorities change. Effective monitoring is essential to determine whether biosecurity and biocontainment practices are working. For example, if a BLV control program is established with the goal being to raise seronegative heifers, then regular monitoring of the serologic status of replacements is necessary to determine if the goal is being met. When a disease outbreak occurs, infection control practices should be reviewed with all personnel. Possible areas of biocontainment lapses should be identified and changes made to prevent future lapses. If a particular practice is not working, find out why and look for other solutions, or remove it from protocols.

Risk communication

Any disease-control program is only as good as its implementation. Biocontainment practices can be time consuming and require extra effort, and it is vital that staff understand the reasons for their implementation. Regular training and review sessions should be held. All farm employees should be involved because effective biocontainment in the calf facility involves the cooperation of personnel from all areas of the farm. A formal, written biosecurity and biocontainment program should be prepared and should be accessible so that it can be referred to as needed. Signs can be posted at critical locations to remind staff and visitors to follow particular practices (eg, to use the footbath). Incentives to aid in staff cooperation may be effective. Staff should also be trained about possible zoonoses and how to avoid exposure for themselves and in-contact family members and friends.

Summary

Biosecurity, biocontainment, and disease risk management on dairy replacement operations are time- and labor-intensive, planned programs.

Oftentimes the value of these programs is realized only after disease is introduced to a facility or a disease outbreak occurs. There is no “one-plan-fits-all”; each plan must be tailored to meet the needs of management’s goals and expectations, and problems specific to a production enterprise or geographic region.

A standard framework applicable to biosecurity programs includes: (1) hazard identification, (2) exposure assessment, (3) risk characterization, and (4) risk management. The discussion presented here helps lay the framework for development and implementation of biosecurity and risk-management programs within dairy replacement facilities.

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